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# Walk and Learn: An Empirical Framework for Assessing Spatial Knowledge Acquisition during Mobile Map Use

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## Abstract

We gladly use automated technology (e.g., smart devices) to extend our hard working minds. But what if such technology turns into mind crutches we cannot do without? Understanding how varying levels of automation in mobile maps might impact navigation performance and spatial knowledge acquisition will provide important insights for the ongoing debate on the potentially detrimental effects of using navigation systems on human spatial cognition. We need to identify the right balance between system automation (support) and user autonomy (self-reliance). Preliminary results of a pilot study performed within a novel empirical framework indicate that it is possible to increase user autonomy and spatial knowledge acquisition without negatively impacting navigation performance and usefulness of the system.

## 1. Introduction

Various research fields have investigated how system automation might influence human knowledge and abilities. It is generally agreed that computers often make decisions originally performed by humans in a (more) efficient way. This has positive and negative impacts on humans as, for example, automation can reduce their physical and cognitive effort (Sheridan 2002). This also holds for navigational tasks, where acquiring spatial knowledge is crucial to orient and move in space without getting lost. Recent developments in self-driving vehicles highlight the need for better understanding human behavior, especially when humans have to take over from automated systems during system failure (Merat *et al.* 2014). The ideal human-system interaction would be to use the best of both human and technology (Sheridan 2002), which we aim for in our research. Specifically, how do we balance the advantages of system automation and the need for human autonomy to maximize both navigation efficiency and knowledge acquisition?

## 2. Balancing Assistance and Engagement

Research investigating mobile navigation aids identified negative impacts on spatial knowledge acquisition, despite being very effective for efficient navigation (e.g. Willis *et al.* 2009). The consequences of automated guidance seem to be a disengagement of navigators' attention from their surroundings (Gardony *et al.* 2013), and split attention between mobile device and the traversed environment (Willis *et al.* 2009).

However, mobile navigation devices should enable pro-active engagement with the environment, which will lead to better spatial knowledge acquisition (Chung *et al.* 2016; Parush *et al.* 2007), as systems might break down, or users might lose the device and suddenly depend on their own abilities (Hirtle and Raubal 2013). The means to design such systems are yet unclear. Systems would need to provide efficient wayfinding support (sufficient system automation) while at the same time engage users during the wayfinding process, such that they learn something about and from the environment (sufficient user autonomy).

Our research aims at finding the right balance between system automation and user autonomy. We are constructing an empirical framework in which we will explore various design solutions for mobile maps. This experimental setup aims to establish how system design decisions might affect users' spatial knowledge acquisition while also measuring navigation performance. The latter is important in ensuring that our experimental designs do not render the navigation task too difficult or too tedious.

A key aspect is that empirical studies with pedestrians are conducted in urban outdoor environments. We ask participants to follow a given route with the help of mobile map applications, which will vary the level of system automation for one or several cognitive processes relevant in navigation (e.g., self-localization or route planning). Adopting a between-subject design, we plan to always test at least two participant groups with different levels of automated features: either automation is permanently present or the user needs to initiate the required cognitive process. Intermediate levels will also be considered.

Subsequent to the assisted route-following task, participants are asked to find the exact same way back without any system assistance. Walking back will assess participants' acquired spatial knowledge. This is a hard task, as wayfinding decisions have to be reversed, and the navigator's perspective of the traversed environment will change. Strategies to encode and decode spatial knowledge vary across individuals and groups (Ishikawa and Montello 2006). A key factor in our analysis will thus be the assessment of differences in spatial abilities.

In order to support our findings, we further measure the navigator's eye movements using a mobile eye tracker to determine the influence of mobile map design on participants' environmental perception. Analyzing areas of interests defined for the route-following task allows for more systematically studying participants viewing behavior, for example, when fixating environmental features with changing perspectives (e.g., original route and return journey).

We hypothesize that increasing user autonomy as a result of lowering system automation will lead to increased spatial knowledge acquisition due to increased active engagement with both the navigation application and the environment.

## 3. Pilot Study

We are currently conducting a field study based on our novel empirical framework which tests the effects of two system automation levels on participants' self-localization process. Constant location updating on the mobile map seems to consume a user's attention (Willis *et al.* 2009), which changes how humans perceive the environment during navigation, and leads eventually to a loss of the fundamental skill of environmental information collection (Parush *et al.* 2007). Here, we report on preliminary results of a pilot study.

### 3.1 Method

Six participants (average=25.5 years) participated in the pilot study. On arrival, all participants filled in a demographic questionnaire, donned the mobile eye-tracker (Figure 1a), and conducted a training session with the application. Half of the participants used a mobile map, which constantly updated their location on the map ('always-on' group). The second half was instructed to press a button to get their location displayed on the map for ten seconds ('on-request' group). All participants followed the route shown in Figure 1b using one of the two map application types. Once participants reached the destination, they were asked to walk the same route back to the starting point without any mobile map assistance. We recorded hesitations, stops, mistakes, task time, eye movements for both navigation directions, and all interactions with the application (e.g., zoom). After these route-following tasks, participants were to respond to the Building Memory test to assess their spatial memory abilities.

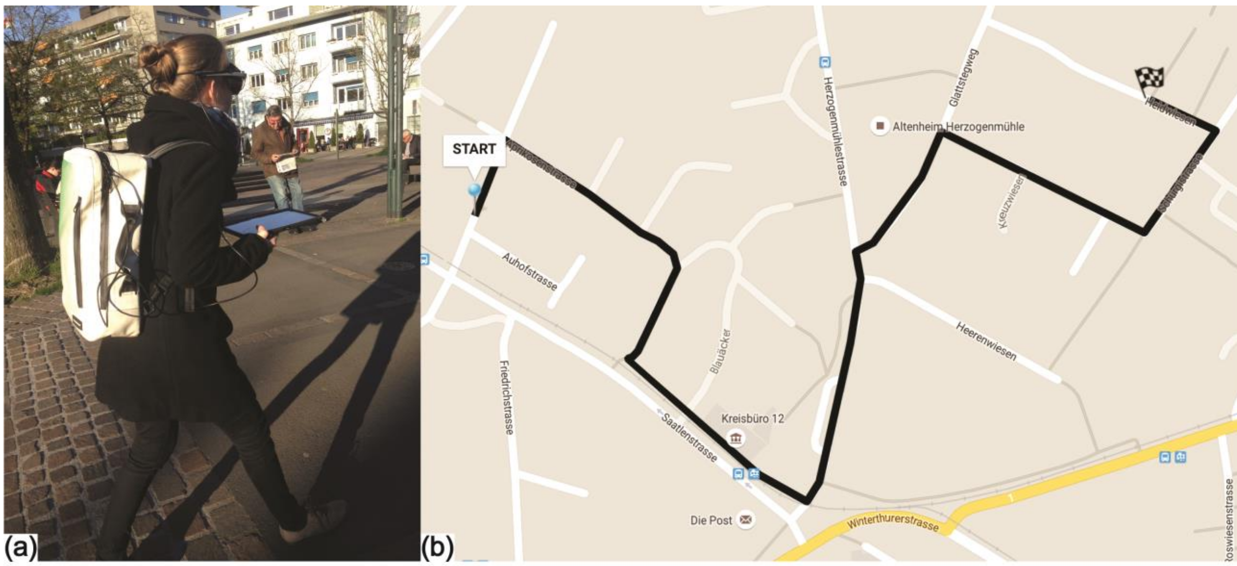


**Figure 1. Participant wearing a mobile eye-tracker while using a tablet device (a) showing the route on the mobile map (b).**

### 3.2 Results & Discussion

Preliminary results indicate that participants with a low level of system automation ('on request') are more actively involved during the navigation process. They interact more with the mobile map, and hesitate and stop more often along the way, possibly to verify that they are still on the right track. The 'always on' group hardly hesitated or stopped during the route-following task. Interestingly, completion time is similar for both groups. Overall, the 'on request' group had no problems in walking back and finding the start point again, while all 'always on' participants made at least one mistake, and one failed to identify the starting point.

Participants in the 'always on' group seem to have slightly lower scores than the 'on-request' group in the Building Memory test. But five of the six participants achieved 20 or more out of 24 possible points, which clearly demonstrates good spatial memory abilities. Still, participants in the 'always on' group did not find the way back without mistakes.

This leads us to conclude at this stage of our research that lowering the level of automation in the self-localization process most likely positively affects spatial knowledge acquisition. It seems possible to increase user autonomy without limiting the assisted navigation process. We still need to confirm this contention once all the empirical data has been collected and analyzed, including the eye-movement recordings.

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